fire

MDPI

Review

Current Standards for the Purposes of Assessing and Classifying Fire Hazards in Historic Buildings

Andrzej Jurecki, Wojciech Grześkowiak and Marek Wieruszewski *

Department of Mechanical Wood Technology, Poznan University of Life Sciences, 60-637 Poznań, Poland; andrzej.jurecki@up.poznan.pl (A.J.); wojciech.grzeskowiak@up.poznan.pl (W.G.)
* Correspondence: marek.wieruszewski@up.poznan.pl

Abstract

The utilisation of fire resistance control systems in contemporary timber construction and the conservation of historic edifices has emerged as a pivotal solution, superseding conventional mandatory systems. Such approaches are particularly beneficial for the rational protection and assessment of unique buildings of historical or cultural significance. The objective is to achieve a balance between the necessity of protecting often irreplaceable structures and their contents, and the aspiration to preserve significant historical or cultural elements of the construction. The article provides a synopsis of fundamental American and European standards, with a particular emphasis on Polish and German standards, and addresses issues related to the implementation of quality and material constraints when developing the scope and methodologies for fire protection in historic buildings. The current state of knowledge on the natural fire resistance of wooden structural elements in historic buildings is defined, and the level of risk is described. The direction of adapting European standards for fire protection of historic wooden buildings to North American standards is indicated. The paper confirms the exemplary adaptation of ASTM standards to UNESCO requirements and provisions in the field of monument protection, as well as the need for changes in European standards.

Keywords: design; fire safety; historic buildings; fire protection; standards

check for updates

Academic Editors: Yongzheng Yao, Zihe Gao, Jinlong Zhao and Qiang Wang

Received: 27 September 2025
Revised: 15 October 2025
Accepted: 16 October 2025
Published: 22 October 2025

Citation: Jurecki, A.; Grześkowiak, W.; Wieruszewski, M. Current Standards for the Purposes of Assessing and Classifying Fire Hazards in Historic Buildings. *Fire* **2025**, *8*, 410. https://doi.org/10.3390/fire8110410

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Fire safety is a fundamental element in the design, construction, and operation of buildings. Its primary goal is to protect human life, health, property, and the environment from the dangers of fire and explosions. Achieving this goal requires a comprehensive approach that encompasses several interrelated measures. Key objectives include preventing fires, limiting the spread of fire and smoke inside and outside buildings, maintaining the load-bearing capacity of structures for a specified period of time, ensuring conditions for the safe evacuation of people, and enabling effective rescue and firefighting operations [1,2].

Building regulations reflect social expectations regarding minimum requirements for health, safety, and well-being, as well as environmental, energy, and cultural protection [3,4]. In the context of globalisation and the increasing complexity of construction projects, the importance of harmonised national and international regulations is becoming increasingly apparent. International standards and codes play a key role in promoting consistency in fire safety practices around the world [5,6]. They facilitate trade in construction products and services and serve as a platform for the exchange of best practices and the implementation of technological innovations. At the same time, national regulations are responsible

for adapting these international standards to specific local conditions, legal systems, and cultural circumstances. They take the form of normative standards, describing the acceptability or requirements for materials, products, and systems. Examples include the American NFPA (National Fire Protection Association) [7] or the European CFPA Europe (Confederation of European Fire Protection Associations) [8].

The International Fire Code (IFC) (2021), published by the International Code Council (ICC), establishes minimum requirements for fire prevention and fire protection systems. It is widely adopted or referenced in various jurisdictions around the world. The code covers a wide range of topics, including general precautions, emergency planning and preparedness, fire department access and water supply, automatic sprinkler systems, fire alarm systems, special hazards, and the storage and use of hazardous materials. A particular aspect of the IFC [9] is its approach to historic structures. The code explicitly recognises that such structures, by their nature, typically do not meet all modern fire codes. Therefore, the provisions of the IFC generally do not apply to historic buildings, except in areas where, in the opinion of the fire code official, there is a "clear danger to life or property." This approach is consistent with the Polish exemption mechanism provided for in the Building Law.

Although the NFPA is primarily a US-based organisation, its extensive portfolio of over 300 codes and standards has a significant international impact. These standards are developed based on the rapidly changing needs of the industry, evolving technologies, sound scientific research, and the practical experience of experts in the field. The International Fire Code (IFC) is designed to be compatible with NFPA standards, and specific NFPA codes, such as NFPA 1 [10] and NFPA 704 [11] (relating to hazard communication), are referenced in the IFC, demonstrating their interconnection and global reach.

In the US, fire protection systems typically provide two or four hours of protection [12]. Proof of fire resistance is primarily based on the enclosure factor—fire cannot escape the interior for a specified period of time. The European Union plays a key role in harmonising building regulations, including fire safety, through a system of standards (Eurocodes) and regulations on construction products (CPR) [13,14]. In Europe, the fire resistance of building elements is assessed by load-bearing capacity (R), integrity (E), and fire insulation (I) according to EN 13501-2 (REI classes) [15]. The Polish legal system for fire safety is extensive and multi-level, comprising laws, regulations, and institutional guidelines. It aims to ensure comprehensive fire protection in all types of buildings. The analysis of fire safety standards and regulations for timber and historic buildings in European countries and worldwide is a complex issue, requiring consideration of both general building regulations and specific heritage protection regulations. Table 1 below provides an overview of key international organisations and their contribution to fire safety.

Table 1. Summary of key standards in the field of fire protection.

Organization	Primary Area of Activity/Role	Key Standards/Guidelines/Codes
ISO (International Organization for Standardization)	Fire safety engineering (performance-based approach), quality management, environmental management, occupational health and safety	ISO 23932-1 (General principles of fire safety engineering), ISO 24679-1 (Performance of structures under fire conditions), ISO 9001, ISO 14001, ISO 45001 [16–20].
ICC (International Code Council)	Development of model building and fire codes	International Fire Code (IFC).
NFPA (National Fire Protection Association)	Development and publication of fire safety codes and standards	Over 300 codes and standards, e.g., NFPA 704 (hazard identification) [11]

Table 1. *Cont.*

Organization	Primary Area of Activity/Role	Key Standards/Guidelines/Codes
UNESCO (United Nations Educational, Scientific and Cultural Organisation)	Protection of world cultural and natural heritage, fire risk management in heritage sites	UNESCO Fire Risk Management Guide [21]
ICOMOS (International Council on Monuments and Sites)	Conservation of cultural heritage, development of conservation doctrines and techniques, expert advice.	ICOMOS Charters (e.g., Principles for the Analysis, Conservation, and Restoration of Architectural Heritage Structures) [22]
CFPA Europe (Confederation of Fire Protection Associations Europe)	Development of practical guidelines for fire protection in Europe	Guideline No. 30:2013-Managing Fire Protection of Historic Buildings [23]

Despite the uniform European fire protection classification system [24], national regulations require different resistance times. In Germany, Austria, and Switzerland, the F 90 (DIN 4102) [25]/REI 90 (EN 13501-2) [15] classification is used, while in Poland, France, Spain, and Italy, REI 120 applies. In Germany, the old DIN 4102 [25] standard, "Fire properties of building materials and components," is still in effect, despite its withdrawal, and the European standard EN 13501 [26] has not been incorporated into German law. In addition, there are additional regulations in the German federal states [27], according to which fire protection systems are only used after approval by monument and building protection authorities (e.g., DIBt). The DIN 4102 [25] standard specifies the fire resistance class of a construction product using the code letter F and the fire resistance time. Analogous fire safety standards are required for the acceptance of buildings in various EU countries and around the world. In many cases, ensuring the appropriate fire resistance class of a structural element does not require the designer to perform complex calculations and is limited to selecting the properpassive protection system, e.g., using fire-retardant paints, sprays, or boards. The effectiveness of fire protection systems is assessed based on standardised fire resistance tests, which utilise the so-called standard temperature-time curve.

In some situations, it may be necessary to determine the fire resistance of a structural element by calculation. In exceptional cases, this may also apply to structural elements that are not protected by any fire protection system. This may be the case for existing buildings (including historic buildings), unusual structural forms, and buildings for which an individual fire safety strategy has been developed using fire engineering methods [28].

Fire protection of historic buildings is particularly complex due to the need to reconcile stringent safety requirements with the protection of historical, artistic, and scientific values. Fundamental conservation documents, such as the Athens Charter (1931) [29] and the Venice Charter (1964) [30], emphasise the paramount importance of preserving the original message, memory, and tribute to the past that are embedded in architectural heritage. Contemporary fire safety measures, such as the installation of visible systems or the replacement of original components with modern fire-resistant materials, can directly conflict with these principles by altering the original design and aesthetics [31]. The main disadvantage of current fire safety standards is their limited applicability in historic buildings, especially when safety solutions are limited in some way. These restrictions result from aesthetic and conservation considerations, which may prevent compliance with normative requirements for fire compartments or the use of standard solutions due to the structure and size of the monument. In such situations, equivalence provisions apply. Alternative solutions should be verified by monument protection and building authorities. The relevant official should confirm that the proposed solution complies with standards and meets at least conditions equivalent to general regulations [32].

International organisations play a key role in developing guidelines and recommendations that help protect cultural heritage from fires around the world.

UNESCO is the leading organization promoting the protection of cultural and natural heritage worldwide [33]. A new UNESCO report [21], presented in November 2024, provides comprehensive guidelines for fire risk management in cultural and natural heritage sites, promoting an innovative and holistic approach that integrates prevention, mitigation, response, and recovery. The guide recommends practical measures such as creating fire compartments, installing early detection systems (e.g., smoke and heat detectors), providing adequate fire extinguishing systems (e.g., sprinklers, sprinkler systems), ensuring clearly marked and unobstructed escape routes and implementing structural protection measures. Importantly, UNESCO's approach emphasises the intrinsic role of heritage itself in disaster risk reduction and resilience building. It encourages the use of traditional ecological knowledge, skills, and practices of local communities, recognising their value in contributing to the preservation of ecosystems and mitigating fire risk in a context-specific manner.

Key ICOMOS [22] documents, such as the "Principles for the Analysis, Conservation and Restoration of Architectural Heritage Structures," promote a multidisciplinary approach to conservation. These principles emphasize that the value of architectural heritage lies not only in its appearance but also in the integrity of all its components, reflecting the specific building technology of a given era. This doctrinal position implies that fire safety interventions should respect original construction methods and materials, discouraging the removal of internal structures solely for safety upgrades.

CFPA Europe provides practical, consensus-based guidelines for fire protection in European countries. Its "Guideline No. 30:2013—Fire Protection Management of Historic Buildings" [23] offers comprehensive, practical advice for owners, managers, and custodians of historic properties.

In the case of historic buildings, it is often necessary to deviate from the general provisions of the Building Law and the Regulation on Technical Conditions. In Poland, this is possible under Article 9 of the Building Law [34], which allows for derogations from technical and construction regulations in particularly justified cases, after obtaining the consent of the minister responsible for construction, planning and spatial development, and in the case of historic buildings, also after consultation with the conservator of historic buildings.

Technical reports on fire safety are often prepared for historic buildings. These documents analyse the specific characteristics of the building and propose alternative or replacement solutions that will achieve an equivalent level of safety without compromising the historic value. Many historic buildings, especially those of great importance or large volume, require the installation of fire protection systems and smoke and heat exhaust ventilation systems. Other modern solutions are also often used, such as mist hydrants, which minimise damage when water is used. The guidelines of the General Conservator of Monuments emphasise the need to use traditional techniques, technologies, and materials. If replacement of elements is essential, the guidelines also stress the importance of striving for reconstruction in accordance with the originals. In the case of wooden structures, replacement is only permissible in the event of destruction or decay of the structure. For many historic buildings, it is necessary to develop fire safety instructions that specify in detail the procedures to be followed in the event of a fire, the location of firefighting equipment, escape routes, etc.

Reaching a consensus is often difficult from a legal standpoint. However, some systems attempt to quantify equivalence, such as the Fire Safety Equivalence System (FSES) published in NFPA 101A [35]. These systems are developed for specific types of structures

and must be adapted to local regulatory requirements. Polish fire regulations, although strict, offer mechanisms for adapting requirements to the particular nature of wooden and historic buildings, primarily through the possibility of using alternative and substitute solutions, agreed with the relevant authorities. It is crucial to take an individual approach to each building and to seek solutions that will ensure safety without compromising its historical value.

Additionally, proactive planning and comprehensive documentation are essential. The CFPA Europe guidelines [23] and the new UNESCO guide [21] place great emphasis on risk assessment, fire safety manuals, fire safety logs, and damage reduction plans. This underscores that fire safety is not just about installing equipment, but also about meticulous planning, comprehensive documentation, and ongoing management. These administrative and operational measures are crucial for preparedness, effective response, and damage minimisation, especially in the case of unique cultural resources. This also highlights the importance of human factors, such as trained personnel and clear emergency procedures.

Finally, global cooperation and knowledge sharing in heritage protection are evident. The existence of guidelines from UNESCO [21], ICOMOS [22], and CFPA Europe [23], as well as discussions on technologies such as fog hydrants and lessons learned from events like the Notre Dame fire [36], points to an active international exchange of knowledge and best practices. This collaborative environment fosters the development of specialised solutions and promotes a more informed, adaptive approach to fire risk management in sensitive historical contexts around the world. The tragic fire at Notre Dame Cathedral in 2019 is a stark, high-profile global example that highlights the devastating impact of fires on irreplaceable cultural heritage. Such events underscore the critical and urgent need to develop robust, adaptive, and well-planned fire protection strategies for historic buildings around the world.

The lessons learned from these and other incidents consistently highlight the need for a sensitive, individualised approach to fire safety in the context of cultural heritage. This includes promoting interdisciplinary collaboration among experts and a willingness to make pragmatic compromise decisions, often based on alternative solutions and advanced numerical analyses, to achieve safety objectives without compromising the integrity of historical materials and structures.

The properties associated with the protection of historic buildings differ from those of other buildings. The goal is not always solely to preserve the structure—often, keeping its contents is equally essential. The preservation of aesthetic qualities and internal and external architectural details is usually unique and forms part of the historical record. Therefore, the conservation of historic buildings must take into account the individual needs of the building, which often do not comply with the typical regulatory requirements for new buildings.

These ideas form the basis of the NFPA Code for Fire Protection of Historic Structures [37]. NFPA 914 [37] defines fire safety requirements for historic buildings and for the people who operate and visit them. The scope of fire protection covers current use, renovations, and restorations, while recognising the need to preserve the historic character of the building. The code emphasises the goals of protecting life and property, which apply to both prescriptive and performance-based solutions based on fire scenarios. NFPA 914 also addresses issues related to the protection of museum and library collections, which are regulated in NFPA 909 (Code for the Protection of Cultural Resources) [38].

The process described in NFPA 914 [37] begins with a detailed study documenting the historical elements, spaces, and features of the facility. Potential fire hazards and requirements consistent with safety objectives are identified to minimise the impact on the historical features of the monuments. Security solutions are selected from among traditional

measures, normative solutions, or based on risk analysis, to meet safety objectives with minimal impact on historical value. All parties involved must understand the features of the building that need to be protected and take them into account in periodic inspections of the work performed.

Engineering Design Standards and Methods

The science of fire risk has achieved a high level of predictive capability. An engineering approach to structural design with regard to fire conditions was already included in the Swedish textbook Fire Engineering Design of Steel Structures from the 1970s [39]. This effort was later the starting point for the development of Eurocodes. Tools for the engineering fire protection of structures are included in numerous chapters of the SFPE Handbook of Fire Protection Engineering [40,41], while engineering standards appeared much more slowly in both Americas. Currently, Eurocodes support the engineering design of fire protection for structures, and the SFPE, together with the American NFPA and AISC, plays a key role in the development of these methods.

The engineering approach takes into account the anticipated fire load and fire compartmentation in a building, rather than using standard time-temperature curves. This enables the modelling of a building's thermal response and the structural response to fire exposure [42]. The fire protection design of historic buildings goes beyond the scope of normative building codes and aims at solutions that are more sustainable and cost-effective in the long term. It is based on an analysis of fire risk and building failure. The overall goal of fire protection design is to provide a safe, comprehensive, and robust solution that may be more balanced. Regulations often allow for "alternative means and methods" subject to approval by the competent authority. The introduction of structural protection based on technical standards will be gradually implemented in national building regulations.

One of the key elements of this package is NFPA 557 [43], which defines the methodology for determining fire load in terms of the thermal energy potential of combustible materials (MJ/m^2). Fire load density (MJ/m^2) is defined as the thermal energy, expressed in MJ, that can be generated by the combustion of combustible materials stored, produced, processed, or transported continuously in a room, fire zone, or solid material storage area, per unit area of that facility expressed in m^2 (PN-B-02852) [44]. The calculations require the determination of the limit of the risk of structural collapse, which is also subject to approval by the relevant authority. NFPA 557 [43] quantifies the fire hazard in different types of rooms as a function of the kind of structure and the presence of active fire protection measures. SFPE S.02 [45] provides methods for calculating the thermal exposure of structural elements to fire, considering both local and fully developed fire scenarios in the zone. It is based on a deterministic worst-case approach and considers heat transfer from the fire to the structure or to fire barriers. It includes requirements for analysis methods, input data definitions, and method verification. The final element of the assessment is the response of the structure to fire, as described in ASCE/SEI 7.6 [46–48]. It specifies the magnitude of the gravitational load imposed on the structure during the design fire exposure. As a result, fire reduces the strength and stiffness of the structural material, affecting the thermal expansion of elements and connections.

2. Materials and Methods

Review and Analysis of Standards

Searching for data on fire safety standards is a complex process, as the regulations are multifaceted and include both legal acts and technical standards. Data regulated by legal acts (laws, regulations) has been obtained—these are mandatory and define general principles and requirements. These include, for example, the Fire Protection Act and the

rules on technical conditions. These documents concern both associations of states, as in the case of the European Union, and the requirements of individual member states and non-member states. In this case, these are national standards and European Standards (EN)—these specify detailed technical requirements, test methods, classifications, etc. Their application is often voluntary, but it may be mandatory if they are referred to in legal acts. Basic sources of applicable regulations were used through access to official government portals or commercial legal databases.

An overview of fire safety standards and rules was taken into account, the purpose of which is to:

- Protect human life: Standards specify requirements for escape routes, fire alarm systems, emergency lighting, and the time during which the building structure must remain stable to allow for safe evacuation.
- Limiting material losses: Regulations and standards govern the use of non-combustible or flame-retardant materials, fire extinguishing systems, fire barriers, and installation safeguards, intending to limit the spread of fire and minimising damage.
- Ensuring continuity of operation: Standards help in planning solutions that support the fastest possible restoration of normal functioning.
- Standardisation of requirements: Thanks to standards, manufacturers know what characteristics their products must have to be approved for use in construction. This facilitates design and construction and ensures consistency in safety.
- Facilitation of design and construction: Standards provide detailed technical guidelines that are essential for architects, engineers, and contractors. They eliminate the need to create your own solutions from scratch each time, which speeds up construction processes and reduces the risk of errors.
- Providing a legal basis and accountability: Standards are often referenced in legislation, making them mandatory. They form the basis for conformity assessment, inspection, and verification. In the event of a fire, compliance with standards is crucial for determining liability.
- Support for innovation and technological development: Standards are updated to take into account new technologies and solutions that can improve fire safety. They provide a framework for research and development in the field of fire protection materials and systems.
- Facilitation of international cooperation: Some regulations and standards are harmonised with European standards (EN), which facilitates international cooperation in design and construction.

3. Results and Discussion

3.1. Fire Classification

Fire classification may apply to construction products, product assemblies, or building elements. There are three basic types of fire classification in the regulations: reaction to fire, fire spread, and fire resistance.

In European standard EN 13501-1:2018 [26], the classification procedure covers all products and components, considering them in relation to end uses divided into three categories: building materials, floor elements, and thermal insulation materials. Construction products are classified according to standardised tests into Euroclasses A1, A2, B, C, D, E, and F. Materials classified in a given class meet the requirements of all subclasses associated with it. Classes A1 and A2 denote non-combustible materials, while materials in classes B–F show increasing flammability. Flooring materials are also classified in classes A1–F.

The EN 13501-2 (2023) [15] standard on the fire resistance of building elements distinguishes between the functions of elements. Elements with a load-bearing function must be

classified as "REI" (load-bearing capacity, integrity, insulation) or "R" (load-bearing capacity) when exposed to fire on one side, depending on their function. The article presents arguments for and against a uniform approach to the classification of the fire resistance of structural elements. Tall and multifunctional buildings pose a high fire risk, which largely depends on the materials used in their construction.

In accordance with the current Fire Safety Regulation (introduced in 2007), standard EN 13501-1 [26] and related standards define the classification of the reaction to fire of building materials through standards and test guidelines. In addition, EN 13501-1 introduces subclassifications related to smoke emission and the formation of burning droplets. The symbol "s" refers to the level of smoke emission (from 1: none/low to 3: high), and the symbol "d" refers to the formation of burning droplets or particles (range from 0: none to 2: high). For class E, there is one subclass, "d2." For flooring materials, there is an additional classification only for smoke emission. In practice, materials classified in classes A1 and A2 are completely non-combustible, while materials from B to F can sustain fire to varying degrees.

3.2. American Standards

3.2.1. ASTM E119 Standard

The ASTM E119 [49] standard specifies test methods for testing the fire resistance of structural components in load-bearing buildings. It is also used for assemblies of structural elements, such as floor and roof beam assemblies and other permanent structural components. The tests are comparative to standardised fire conditions and should not be used to predict behaviour in other fire conditions. The standard was developed in accordance with international standardisation principles (WTO TBT Resolution).

3.2.2. ASTM E84

ASTM E84 [50] is a standard method for determining the spread of flame on the surface of building materials and measuring smoke density. The test is performed on a sample 20 inches (50.8 cm) wide and 24 feet (7.32 m) long, with controlled airflow and a flame of adjustable intensity. This method provides comparative measurements of flame spread and smoke density under specified exposure conditions, and the results are reported as flame spread and smoke density indices. The ASTM E84 [50] method does not measure heat conduction or the effect of flame spread from adjacent combustible surfaces. It is used to determine the relative behavior of combustible surfaces (walls, ceilings) when burning. During the test, the sample is placed horizontally, with the surface facing the ignition source. The material or assembly of test items may be supported in the test position by additional supports or embedded. The purpose of the test is to observe the spread of flame on the surface of the sample. The results are reported in terms of flame spread and smoke development indices. However, it should be noted that there is not always a direct correlation between these indices. For example, the presence of supporting materials under the sample may reduce the flame spread index compared to a suspended sample test. This method does not always reflect behavior in a real fire.

3.3. German Standard DIN

DIN 4102-1

The DIN 4102-1 [51] standard concerns the fire resistance of building materials and components (Class A—building materials, requirements and testing). It regulates the fire resistance of materials when exposed to fire, defining fire behaviour classes and requirements for each class. The fire reaction class of materials is determined based on these tests. DIN 4102-1 [51] refers to several related standards and test methods. It defines classes of

building materials (A1–A2–B–C–D) and test conditions for each class. For example, class A1 includes completely non-combustible materials (minerals, steel, glass, etc.), while the subsequent classes A2, B, C, and D include gradually combustible materials, subject to additional criteria.

The presented standards can be divided into basic groups covering measurement areas. Below is a brief explanation of each of these areas in the context of fire protection:

3.4. Reaction to Fire

Reaction to fire refers to how a building material behaves when exposed to fire, i.e., how quickly it ignites, how intensely it burns, whether it emits smoke, or drips. This is a key parameter for fire safety. Materials are classified according to European standards (e.g., EN 13501-1 [26]) based on testing, receiving classes from A1 (non-combustible) to F (highly combustible), with additional markings for smoke emission (s1, s2, s3) and burning droplets/particles (d0, d1, d2).

3.5. Fire Resistance

Fire resistance is the ability of a structural element (e.g., wall, ceiling, door, column) to maintain its functions (load-bearing, tightness, insulation) in fire conditions for a specified period of time. It is measured in minutes and classified according to standards (e.g., EN 13501-2). Examples of markings are:

- R (fire resistance)—the ability to bear loads.
- E (fire integrity)—the ability to prevent the spread of flames and hot gases.
- I (fire insulation)—the ability to limit heat transfer.

Fire Load Measurement

Fire load measurement is the process of estimating the amount of thermal energy that can be released as a result of a fire in a given space. Fire load is expressed in units of energy per unit area (e.g., MJ/m^2). It includes the potential energy stored in combustible materials in a room. Fire load testing is necessary for:

- Proper design of fire protection systems.
- Determining the fire resistance requirements for structural elements.
- Assessing fire risk and planning safety strategies.

3.6. Protection of Historical Monuments

The protection of historical monuments in the context of fire safety is a specific and extremely complex field. The aim is to protect unique and often priceless historical buildings from destruction by fire, while respecting their architectural integrity and cultural value. The challenges include:

- The use of non-invasive protection systems (e.g., smoke detectors, mist sprinklers that minimise water damage).
- Difficulties in modernising existing structures (often made of wood or materials with low fire resistance).
- The need to take into account the historical layout of the building when planning escape routes and access for the fire department.
- Frequent deviations from standard fire regulations in consultation with the conservator.

3.7. Reference Standards

Reference standards are standards (European, international) [Eurocode 1] referred to by legal regulations or other standards, specifying requirements, test methods, classifications, or terminology. When a legal act refers to a specific standard, the application of that

standard becomes mandatory in a given context. They are the foundation for consistency and uniformity in the design and implementation of fire protection systems.

Engineering Design

Engineering design in fire protection involves the application of engineering principles to the analysis, planning, and implementation of solutions aimed at ensuring the fire safety of buildings. It includes:

- Designing passive fire protection systems: e.g., selecting appropriate materials and components with the required fire resistance, designing fire zones and escape routes.
- Designing active fire protection systems: e.g., sprinkler systems, fire alarm systems, smoke extraction systems, and hydrants.
- Fire risk analysis: assessment of the likelihood of a fire occurring and its potential consequences.
- Fire and evacuation modelling: using advanced simulation tools to predict the behaviour of fire and people in fire conditions.
- Development of fire safety instructions.

All these areas are closely interrelated and form a comprehensive fire safety management system (Table 2).

Table 2. Comparison of standards in selected countries.

Area	US Standards	German Standards	EU Standards (Poland)
Reaction to fire	ASTM E84—tunnel test (20″ × 24′)—flame and smoke spread index [50]	DIN 4102 1—classes B1 (not easily flammable), B2 (flammable), B3 (easily flammable) [51]	EN 13501 1—Euroclasses A1–F—subclasses s_1–s_3 (smoke), d_0–d_2 (droplets) [26]
Fire resistance	ASTM E119—macro furnace (time temperature)—classes 1 h, 2 h, 3 h [49]	DIN 4102 2/16—"Brandschacht" and macro-furnace—classes F 30, F 60, F 90 [25]	EN 13501 2—classes R, RE, REI (R = load-bearing capacity; E = tightness; I = insulation) [15]
Fire load measurement	NFPA 557—load density (MJ/m^2) [43]	– no dedicated standard (analyses according to DIN/EN are used)	– no European standard, NFPA 557 or national guidelines are used
Protection of historical monuments	NFPA 914—Code for the protection of historical monuments, NFPA 909—Protection of cultural resources [37,38]	– no specific document; DIN 4102 + conservation guidelines are used	– no dedicated standard; EN 13501 + national conservation regulations are used
Reference standards	ASTM C569, D6513, E176, E177, E691, E814, E2226 [52–58]	DIN 50055, 51622, 51900-2/-3, 53436-1/-3 [59–63]	EN ISO 1182, 1716, 11925-2, 9239-1, 13823, 15725 [63–68]
Engineering design	SFPE S.01, S.02 ASCE/SEI 7.6 [45–47]	Eurocodes EN 1991-1-2, EN 1992-1-2,) [69–71]	Eurocodes (EN 1991-1-2, EN 1992-1-2,1995-1-2) [69–72]

Notes: ASTM E84 [50] vs. EN 13501 1 [26] vs. DIN 4102 1 [25]—basic fire reaction tests in the USA, EU, and Germany; ASTM E119/DIN 4102 2/16/EN 13501 2—basic methods for testing fire resistance (load-bearing capacity, tightness, insulation). NFPA 914/909 [38] are the only American documents dedicated to the protection of historic buildings. In the EU and Germany, the protection of historic buildings is regulated by conservation law in conjunction with general fire safety standards. Eurocodes and SFPE/ASTM/ASCE standards offer an engineering approach that is increasingly used in the analysis of historic buildings when full-scale furnace tests are not possible.

In East Asian countries, especially Japan and China, many ancient and valuable buildings have been preserved, mainly temples, palaces, and pagodas, most of which are wooden structures. Their approach to fire protection combines traditional techniques

with modern technologies and is deeply rooted in history. In most Asian countries, the American NFPA 914 and 909 standards are implemented as a model for protecting historic buildings from fire [73]. Due to frequent fires and earthquakes throughout its history, Japan has developed specific and very restrictive methods of protecting monuments. Water mist and sprinkler systems are commonly used, especially in the most sensitive areas (e.g., roofs and floors). Many historic complexes (e.g., temples in Kyoto) maintain water reservoirs near buildings to serve as an easily accessible source of water. Advanced sensors (often sensitive to smoke, heat, and sparks) are used and connected to central monitoring systems. Many old Japanese temples used elements such as clay plaster and earth insulation in walls, which naturally increase the fire resistance of wood. Japanese building law (Building Standards Law) recognizes many traditional wall constructions, including "Dozo," frame walls protected with a traditional Japanese layer of plaster, and "Shinkabe" (earth-plaster wall with bare wooden frame) with a layer of soil. They are only classified as fire-resistant structures. This is not because the fire resistance of traditional earth walls is inferior, but rather because research and data on the fire resistance of traditional wooden structures are insufficient. The traditional wooden earthen wall construction has recently been reevaluated from the perspective of recycling building resources. Considering the preservation of the historical urban landscape and the preservation and utilization of historic buildings, improving the fire resistance of traditional wooden construction methods is extremely important [74].

In Taiwan, the protection of historic districts has been included in the Cultural Heritage Preservation Act since 2005, and by 2013, 11 historic districts had been certified under it. Taiwan's historic districts are typically characterized by narrow streets, a high density of old buildings, and vacant properties. In recent years, several historic buildings in Taiwan have been destroyed by fire, which has necessitated work to improve fire safety management. In order to implement appropriate fire safety measures and reduce the risk of fire in historic buildings and their surroundings, it is necessary to strengthen rescue and firefighting services and to promote awareness among residents of fire prevention practices and the use of safety measures [75]. In China, especially in the case of such huge complexes as the Forbidden City, bronze vats filled with water were traditionally maintained, and historical villages have methods that are scaled and often draw on a thousand-year-old tradition. In historic complexes, there is a total ban on smoking, bringing matches/lighters, and using sources of fire. Where possible, modern fire-retardant wood impregnation is used and stone and brick barriers are built between wooden buildings to limit the spread of fire.

Due to its history, Hong Kong has a diverse range of historic buildings, including traditional Chinese clan temples, Western-style residences, and public buildings (e.g., police stations). The applicable prescriptive (mandatory) fire safety codes pose an inevitable challenge when renovating or altering historic buildings. It is necessary to minimize interference with the historic fabric, appearance, and aesthetics, while ensuring an adequate level of life safety. Historic buildings often have fewer fire safety features than required by modern regulations. Typical problems include, for example, wooden structures due to the risk of fire and rapid spread of fire, limited space, etc. The main difference between East Asia and Europe in the context of wooden monuments lies in the massive scale of wooden architecture and the acceptance that wood is a combustible material. Asian standards based on conservation requirements allow the use of thermal monitoring to detect temperature increases, modern fireproofing of wood, and the introduction of physical barriers (fire walls), provided that they do not distort the authenticity and aesthetics of the monument [76,77].

3.8. Fire Protection

Precautions During Construction, Repair, and Renovation Work

Particular caution must be exercised during construction, repair, and renovation work on historic buildings. NFPA 914 [37] emphasises the need for such precautions. Flammable materials and construction equipment used on site, as well as activities that could cause ignition, pose a hazard. Empty spaces and flammable structural elements can accelerate the spread of fire. Many catastrophic fires in historic buildings have occurred during renovation work (e.g., the fire at Windsor Castle in 1992, the fire at La Fenice opera house in Venice in 1996, and the fire at Notre-Dame Cathedral in 2019) [36,78]. Therefore, during renovations, it is crucial to monitor fire risks and implement procedures to reduce the danger.

Analyses of the fires at Notre-Dame Cathedral in Paris (15 April 2019) and Windsor Castle (1992), including causes, safety failures, and improvements made, point to renovation and restoration work as the main cause of these events. The fire that destroyed the roof and spire of the cathedral was officially declared an accident. The most likely cause was a failure of the electrical system related to the ongoing renovation work. The roof structure of the medieval roof truss was made of oak. Although the alarm was triggered, there was an error in its interpretation and location, and the spread of the fire was the result of a lack of fire barriers and fire protection systems, including sprinklers. The difficulty in accessing the source of the fire limited the extinguishing of the roof and spire (where the fire broke out).

The reconstruction of the spire and oak roof in accordance with Viollet-le-Duc's original design aims to preserve authenticity. Key improvements focused on a modern fire protection system and advanced fire detection and extinguishing systems. An additional solution was the introduction of fire barriers to slow down the possible spread of fire. These changes contribute to the preservation of authenticity in the conservation of monuments, creating a framework for renovation projects that will have to meet contemporary disaster prevention requirements [79]. Renovation work was also the cause of the fire at Windsor Castle. The immediate cause was damage to a construction spotlight near the altar in the chapel, which set fire to the curtain. The cause was the lack of functioning alarms/warning systems and the lack of an appropriate response. The lack of structural safeguards ultimately caused damage to the structure with limited access to firefighting resources. The renovation integrated modern technologies with the historic structure by installing a sprinkler system. The introduction of improvements to outdated electrical systems and installations, as well as concrete and steel fire barriers and bulkheads inside the historic structure, helped to limit the potential fire to a small section [80].

3.9. Prevention

Fire prevention is crucial in historic buildings, as any fire will cause some damage to the structure or contents. Historic buildings are also often used for research or educational purposes, which requires access to areas not normally open to the public. Research activities must be assessed in terms of fire safety. In addition, in historic wooden buildings, the conditions of use (e.g., lighting, heating, materials used) may increase the amount of combustible materials and potential ignition sources. All activities on historic buildings should be assessed and coordinated, and the relevant permits issued before work begins. Regular technical inspections and strict enforcement of regulations are also necessary [31,32].

3.10. Renovation

One of the main problems with historic wooden buildings is adapting them to modern fire safety regulations. Where strict compliance with new standards has been required, the historical value of the monument has often been significantly reduced (an example is the aforementioned Notre-Dame Cathedral). In the past, fiberglass mats, intumescent fire-retardant varnishes, and wood-penetrating impregnants were used to protect wooden structural elements. These methods were mainly used in the past. Today, the aim is to preserve the original structure using natural materials. Modern fire protection measures are designed to ensure both fire safety and functionality, while preserving the historical character of the structure [81,82].

According to the "alternative approach," if fire regulations cannot be met without interfering with the natural structure of a wooden monument [83], a solution consistent with the character of the building must be found that meets safety and functionality requirements [84,85]. Before developing a specific design solution, non-destructive methods such as endoscopy, acoustic testing, and wood strength testing are used. This allows the condition of existing wooden elements to be assessed, limiting the need for sampling. Finite element models (FEM) used to analyse the behaviour of various parts of historic structures, such as roof trusses, are also an important support. The original changes in the wood structure are examined microscopically, which allows for an accurate assessment of the strength and resistance of all wooden elements. This makes it possible to precisely classify the strength and fire resistance of individual beams, columns, or roof trusses [86].

3.11. Fire Resistance of Structures

By dividing a building into different fire zones, it is possible to reduce the local fire load [87–89]. However, this does not guarantee that all regulatory requirements are met, as all structural elements, even those in zones with lower loads, must maintain a fire resistance rating of at least 90 min [90]. The most effective way to improve safety is to reduce the total fire load by dividing a building into fire compartments. The roof structure usually accounts for the largest proportion of the fire load. Therefore, the roof (along with any adjacent compartments, such as ceilings, floors, wall cladding, stairs and attic elements) must be adequately protected to prevent fire spreading beyond the designated compartments. In practice, this means that roof components and other compartments must be fire-resistant for at least 90 min—in other words, they must meet the REI 90 rating required by building regulations. To meet these requirements, it may be necessary to use a fire-resistant structure (e.g., a concrete composite with wooden planks) or to reinforce wooden beams [86]. The primary measure to increase safety is to reduce the total fire load by dividing the building into fire zones. The roof structure usually accounts for the largest share of the fire load. The roof (and adjacent zones—ceilings, floors, wall cladding, stairs, and attic elements) must be adequately protected so that "fire cannot spread" beyond designated areas. In practice, this requires that roof elements and other areas be fire-resistant for at least 90 min, i.e., meet REI 90 standards in accordance with building regulations. To meet these requirements, it may be necessary to use a fire-resistant structure (e.g., concrete composite with wooden boards) or to reinforce wooden beams [86]. There are two main types of wooden structural elements that require analysis: floor slabs (floors and ceilings) and load-bearing frames (columns and beams). In addition to the required fire resistance, floor slabs must meet the normative live load (e.g., 400 kg/m^2 or more). The combination of thin concrete (6–8 cm thick) with wooden boards can provide effective fire protection while maintaining a fire resistance rating and load-bearing capacity of 90 min. With a constant cross-sectional reduction factor under fire, the remaining cross-section of the wood should carry the required load. However, it should be noted that in a wooden truss, damage to any node will result in the

loss of the entire structure's load-bearing capacity. Therefore, all nodes (joints between trusses, columns, and beams) are additionally secured mechanically (e.g., with steel rods sealed with epoxy resin) to limit the heating of the joints. Long beams (roof trusses) are reinforced with steel cables and rods inserted and anchored at the ends of the beams, which increases their strength and rigidity. An essential issue in the renovation of historic buildings is to preserve the original layout of the building as fully as possible [91–93].

To determine the required heat release rate and fire intensity, the total amount of combustible material and the assumed fire curve are analysed [94]. When modelling historic wooden structures, it is generally assumed that the fire curve peaks after about 30 min, remains at that level for another 60 min, and then gradually extinguishes over the next 45 min. The total duration of a fire modelled in this way is approximately 135 min, which ensures that the load-bearing capacity of the structure is maintained for at least 90 min. Historical studies of the development of the standard time-temperature curve have shown that there is no explicit confirmation of the temperatures in this curve for real fires. Contemporary discussions suggest that this curve is indicative but does not fully reflect a real fire [94,95].

Simulation studies have also shown the impact of ventilation on fire development in a building. The largest fires and heat emissions were observed in the "no ventilation" scenario, characterised by the greatest increase in temperature and heat energy released after 20 min, accompanied by an increase in pressure and a decrease in oxygen levels. In the fire simulation taking into account combustion gases (without ventilation), the highest temperatures, the highest gas concentrations, moderate oxygen depletion, and increased smoke were observed. In contrast, the simulation with full ventilation resulted in lower temperatures, smaller fires near the ventilation openings, virtually stable internal pressure, and the highest oxygen concentrations. These results suggest that ventilation control significantly affects fire dynamics and should be taken into account in the design of historic wooden structures (ASTM 2019 [1,96,97]).

Buildings that are protected by conservation laws or have exceptional historical value (e.g., those listed on UNESCO or national heritage registers) are subject to additional conservation protection. Examples include the National Register of Historic Places in the US, the National Heritage List in England, and the Spanish "Registro de Bienes de Interés Cultural." International organisations such as ICOMOS and the UN (Agenda 2030) also focus on the protection of built heritage. Regardless of legal status, fire remains the main threat to wooden structures—many valuable buildings have burned down throughout history (the Great Fire of Rome in 64 AD, the Great Fire of London in 1666, the fires of New York in the 19th century, the Chicago fire in 1871, etc.) [98–100]. Therefore, regardless of legal regulations, every fire safety measure should be verified in terms of possible fire scenarios and the preservation of cultural heritage.

The main conflicts mainly concern the physical interference of systems with the historical substance of the building (Tables 3 and 4).

Institutional mechanisms for fire control and maintenance in both regions are complex and require cooperation between engineers and maintenance personnel (Table 5).

USA: Often based on PBD (Performance-Based Design), which, instead of rigid quantitative standards (e.g., corridor width), uses computer simulations (e.g., smoke flow and evacuation modeling) to prove that human safety is maintained. The PBD design must be approved by an independent panel of experts (Peer Reviewers), which may include fire protection engineers and heritage experts.

Europe: Although PBD is also used, decisions are more often negotiated through consultation between Regional Fire Services (which issue final approvals) and Conservation Authorities.

Ultimately, in both regions of the world, modern fire control for historic buildings requires an approach based on risk analysis and engineering compromise, where the goal is to achieve an equivalent level of safety without destroying the historical value of the building. It is a dynamic process of continuous negotiation.

Table 3. Escape routes.

Area of Conflict	United States (NFPA)	Europe (National Codes and EN)
Approach to standards	Very restrictive NFPA 101 (Life Safety Code) and International Building Code (IBC) standards. Emphasis on speed and redundancy (multiple exits) of escape routes	Standards are less uniform (national differences) but are based on Eurocodes and EU directives. Focus on horizontal evacuation and escape time.
Main Conflict	The need to build additional staircases (fireproof), enlarge corridors, or install fire elevators, which disrupts the original architectural layout and interiors.	The problem with the width and length of corridors and the fire insulation of old wooden staircases. It is often necessary to add discreet but visible fire seals and fire doors.
Solution	Use alternative engineering solutions (Performance-Based Design-PBD), e.g., extending evacuation time by installing additional sprinklers instead of building stairwells	Approval of longer escape routes provided that the building is fully secured (e.g., with sprinklers) and the fire load is controlled.

Table 4. Sprinkler systems and heritage protection.

Area of Conflict	United States (NFPA)	Europe (National Codes)
Approach to Standards	Sprinklers are standard and often mandatory in public and commercial buildings. NFPA 13 is the starting point	The use of sprinklers is often the result of risk analysis and negotiation. Alternatives are permitted in many countries, but they are strongly recommended in high-value buildings.
Main Conflict	The intrusiveness of pipes and sprinkler heads. The need to drill through walls, floors, and historic ceilings. Concerns about water damage (especially in museums and archives).	The same problem with aesthetic interference. Additionally, the problem of aesthetics and water pressure in old water supply systems.
Solution	Widespread use of water mist systems and pre-action systems (triggered only after smoke and heat detection). Concealing heads in historical elements (e.g., in cornices or under the floor).	Focus on passive systems (impregnation, partitions) as a supplement.

Table 5. Approval Pathways and Responsibility.

Issue	USA (Consensus Model)	Europe (Legal-Administrative Model)
Who Approves	Authority Having Jurisdiction (AHJ)—local authorities, often with the involvement of the fire department (Fire Marshal).	Building Authorities (or equivalent), requiring positive opinions from the Fire Department and the Historic Preservation Officer.
Responsibility	The Fire Protection Engineer is the primary designer and is responsible for demonstrating that the proposed solution is equivalent to the standard (compliance with NFPA/IBC or PBD).	Responsibility rests with the owner/manager of the facility and the fire protection designer, and the process is heavily regulated by national and local law.

Table 5. *Cont.*

Issue	USA (Consensus Model)	Europe (Legal-Administrative Model)
Specialist Institutions	The National Trust for Historic Preservation (a non-profit organization) and NFPA experts provide guidelines.	National Heritage Institutes (e.g., the National Heritage Institute in Poland) and international organizations (e.g., ICOMOS, ICCROM) publish conservation standards with which fire protection solutions must comply.

4. Conclusions

During all phases of designing the renovation of historic wooden structures, it is crucial to continuously assess the performance and effectiveness of the fire protection measures used. Such an assessment, based on an analysis of the phenomena occurring during the development of a fire, determines the solutions adopted. The studies show that, with adequate protection, the wooden structure of a historic building can retain its load-bearing capacity and functionality for at least 90 min (REI 90 class). During this time, any deformation that could damage the structure is unacceptable.

Fire protection solutions must comply with applicable standards and regulations, but traditional standards often refer only to individual elements of historic wooden structures or to the protective materials used. Even if protection compliant with the standards of different countries is used, it may turn out that wooden joints (carpentry connections of beams, wooden dowels, screws, nails, etc.) will reach a critical temperature and become damaged, creating a risk of structural failure. It is therefore necessary to expand the methods to include a computational approach that takes into account the fire load, design configuration, and protection conditions (e.g., ventilation, archiving load).

All protective elements used (e.g., insulating plaster, fire-resistant ceiling) must meet the test requirements specific to the type of structure. This means that protective elements are designed and selected so that their performance is proven under the same parameters at which they were tested, together with the relevant structural elements. For example, if wall protection is to reach a temperature of 200 °C on the protective surface only after 120 min of testing, it can be used to protect a wooden wall that would not burn during that time. However, the regulations stipulate that only partitions certified as fire-resistant (regardless of the material being protected) may be used to protect wooden structures. In practice, this depends on the interpretation of building regulations or additional technical assessment.

This study is of a review nature and focuses mainly on the analysis of regulations and standards concerning the protection of cultural heritage. Further research is planned to examine the possibilities of fire resistance systems for historic buildings based on empirical studies, taking into account advanced modeling methods [101,102].

In summary, the fire protection environment of historic buildings requires a very flexible approach. A fire in a historic building is an irreversible event and requires solutions that go beyond standard building codes. Interdisciplinary action is necessary—cooperation between conservators, fire engineers, and designers—to protect heritage without unduly compromising its historical, structural, and functional value.

Author Contributions: Conceptualisation, A.J. and M.W.; methodology, M.W. and W.G.; software, W.G.; validation, W.G. and M.W.; formal analysis, M.W.; investigation, A.J. and W.G.; resources, A.J.; data curation, writing—original draft preparation, A.J. and W.G. writing—review and editing, M.W.; visualisation W.G.; supervision, W.G. and M.W.; project administration, M.W.; funding acquisition, M.W. All authors have read and agreed to the published version of the manuscript.

Funding: The publication of this study was financed by the Polish Minister of Science and Higher Education as part of the Strategy of the Poznan University of Life Sciences for 2024–2026 in the field of improving scientific research and development work in priority research areas.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data were included in the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Östman, B. National fire regulations for the use of wood in buildings—Worldwide review 2020. *Wood Mater. Sci. Eng.* **2021**, *17*, 2–5. [CrossRef]
2. Mitterová, I. Wood in building structures and its fire protection. *Fire Prot. Saf. Sci. J.* **2022**, *16*, 15–23. Available online: https://kpo.tuzvo.sk/sites/default/files/mitterova_delta_2_2022_fin.pdf (accessed on 27 August 2025).
3. Butt, A.N. Advancing social sustainability in BREEAM New Construction certification standards. *Standards* **2025**, *5*, 8. [CrossRef]
4. Sunikka, M. Policies and regulations for sustainable building. In *Housing and Urban Policy Studies*, 19th ed.; Delft University Press: Delft, The Netherlands, 2001.
5. Buchanan, A. International developments in design for structural fire safety. *Rev. Sul-Amer. Eng. Estrut.* **2004**, *1*, 1. Available online: https://www.semanticscholar.org/paper/International-developments-in-design-for-structural-Buchanan/ef29575e935a43bcedd7ccd514d05fd79acc6c89 (accessed on 12 October 2025).
6. Hirschler, M.M. Procedures for development and revision of codes and standards associated with fire safety in the USA. *Fire Mater.* **2017**, *41*, 1058–1071. [CrossRef]
7. National Fire Protection Association. *NFPA 70: National Electrical Code*; National Fire Protection Association: Quincy, MA, USA, 2007. Available online: https://books.google.com/books?hl=pl&lr=&id=NBMB8vQmzCMC&oi=fnd&pg=PP1&dq=National+Fire+Protection+Association (accessed on 11 October 2025).
8. Epaminonda, E. The Cyprus Family Planning Association and the Cyprus State: A review of a 50-year-old relationship (1971–2021). *Cyprus Rev.* **2022**, *34*, 59–83.
9. International Code Council (ICC). *International Fire Code (IFC)—Fire Prevention and Safety Standards*; ICC: Washington, DC, USA, 2021.
10. *NFPA 1*; Fire Code. National Fire Protection Association (NFPA): Quincy, MA, USA, 2024.
11. *NFPA 704*; Standard System for the Identification of the Hazards of Materials for Emergency Response. National Fire Protection Association (NFPA): Quincy, MA, USA, 2021.
12. Kodur, V.; Kumar, P.; Rafi, M.M. Fire hazard in buildings: Review, assessment and strategies for improving fire safety. *PSU Res. Rev.* **2020**, *4*, 1–23. [CrossRef]
13. Baryłka, A. Issues related to construction products regulations. *Modern Eng.* **2022**, *1*, 9–19.
14. Wall, S. CE marking of construction products—Evolution of the European approach to harmonisation of construction products in the light of environmental sustainability aspects. *Sustainability* **2021**, *13*, 6396. [CrossRef]
15. *EN 13501-2:2016*; Fire Classification of Construction Products and Building Elements—Part 2: Classification Based on Fire Resistance Tests, Excluding Ventilation Systems. CEN-CENELEC: Brussels, Belgium, 2016.
16. *ISO 23932-1*; Fire safety engineering—General principles. ISO: Geneva, Switzerland, 2018.
17. *ISO 24679-1*; Performance of Structures in Fire—General Principles. ISO: Geneva, Switzerland, 2017.
18. *ISO 9001*; Quality Management Systems—Requirements. ISO: Geneva, Switzerland, 2015.
19. *ISO 14001*; Environmental Management Systems—Requirements with Guidance for Use. ISO: Geneva, Switzerland, 2015.
20. *ISO 45001*; Occupational Health and Safety Management Systems—Requirements with Guidance for Use. ISO: Geneva, Switzerland, 2018.
21. UNESCO. *Protecting Cultural and Natural Heritage from Fire: Fire Risk Management Guide*; UNESCO: Paris, France, 2024.
22. ICOMOS. Charter—Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage. In Proceedings of the 14th General Assembly ICOMOS, Victoria Falls, Zimbabwe, 27–31 October 2003.
23. *Guideline No 30:2013 F*; Managing Fire Protection of Historic Buildings. CFPA Europe: Copenhagen, Denmark, 2013.
24. Furmanek, A.F. Impact of the Fire Protection Requirements on the Cultural Heritage of the Polish Old Towns—Selected Problems. *Sustainability* **2025**, *17*, 176. [CrossRef]
25. *DIN 4102*; Fire Behaviour of Building Materials and Elements. Deutsches Institut für Normung (DIN): Berlin, Germany, 1998.
26. *EN 13501-1:2019*; Fire Classification of Construction Products and Building Elements—Part 1: Classification Using Data From Reaction to Fire Tests. CEN-CENELEC: Brussels, Belgium, 2019.

27. Quapp, U.; Holschemacher, K. Heritage protection regulations in Germany and their relations to fire safety demands. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *753*, 042036. [CrossRef]
28. Smardz, P. Eurokody: Wyznaczanie odporności ogniowej elementów konstrukcji. *Ochrona Przeciwpożarowa* **2010**, *1*, 10–16.
29. Iamandi, C. The Charters of Athens of 1931 and 1933: Coincidence, controversy and convergence. *Conserv. Manag. Archaeol. Sites* **1997**, *2*, 17–28. [CrossRef]
30. Jokilehto, J. The context of the Venice Charter (1964). *Conserv. Manag. Archaeol. Sites* **1998**, *2*, 229–233. [CrossRef]
31. Kozłowski, T.; Ivashko, Y.; Belinskyi, S.; Dmytrenko, A.; Ivashko, O. Theoretical and legal rules for the reconstruction of architectural monuments in Ukraine that suffered during the Russian military aggression. *Teka Komisji Urbanistyki i Architektury Oddział PAN w Krakowie* **2022**, *50*, 391–408.
32. Kincaid, S. Fire prevention in historic buildings—Approaches for safe practice. *Hist. Environ. Policy Pract.* **2022**, *13*, 361–380. [CrossRef]
33. Jagielska-Burduk, A.; Pszczyński, M.; Stec, P. Cultural heritage education in UNESCO cultural conventions. *Sustainability* **2021**, *13*, 3548. [CrossRef]
34. Sejm, R.P. Art. 9—[Odstępstwo od Przepisów Techniczno-Budowlanych]—Prawo Budowlane. Dz.U.2025.418. Available online: https://sip.lex.pl/akty-prawne/dzu-dziennik-ustaw/prawo-budowlane-16796118/art-9 (accessed on 20 September 2025).
35. *NFPA 101A*; Guide to Alternative Approaches to Life Safety. National Fire Protection Association (NFPA): Quincy, MA, USA, 2001.
36. Dufraisse, A. Post-fire studies of Notre Dame's framework: Historical and environmental wood memory of the medieval period between the 11th and 13th centuries. Birth of an interdisciplinary project. *J. Cult. Herit.* **2024**, *65*, 17. [CrossRef]
37. *NFPA 914*; Code for Fire Protection of Historic Structures. National Fire Protection Association (NFPA): Quincy, MA, USA, 2001.
38. *NFPA 909*; Code for the Protection of Cultural Resources. National Fire Protection Association (NFPA): Quincy, MA, USA, 2001.
39. Pettersson, O.; Magnusson, S.E.; Thor, J. Fire Engineering Design of Steel Structures. Lund University Research Portal. 1976. Available online: https://portal.research.lu.se/files/5989339/1245743.pdf (accessed on 25 September 2025).
40. DiNenno, P.J.; Hurley, M.J. (Eds.) *SFPE Handbook of Fire Protection Engineering*; National Fire Protection Association: Quincy, MA, USA, 2008.
41. Hurley, M.J.; Gottuk, D.T.; Hall, J.R., Jr.; Harada, K.; Kuligowski, E.D.; Puchovsky, M.; Wieczorek, C.J. (Eds.) *SFPE Handbook of Fire Protection Engineering*; Springer: New York, NY, USA, 2015. Available online: https://download.e-bookshelf.de/download/0008/0074/62/L-G-0008007462-0024373545.pdf (accessed on 27 August 2025).
42. Prasad, K.; Baum, H.R. Coupled fire dynamics and thermal response of complex building structures. *Proc. Combust. Inst.* **2005**, *30*, 2255–2262. [CrossRef]
43. *NFPA 557*; Standard for Determination of Fire Loads for Use in Structural Fire Protection Design. National Fire Protection Association (NFPA): Quincy, MA, USA, 2012.
44. *PN-B-02852*; Ochrona Przeciwpożarowa. Obliczanie Gęstości Obciążenia Ogniowego Oraz Wyznaczanie Względnego Czasu Trwania Pożaru. Polski Komitet Normalizacyjny: Warsaw, Poland, 1994.
45. *SFPE S.02*; Calculation Methods to Predict the Thermal Performance of Structures & Fire Resistive Assemblies. Society of Fire Protection Engineers: Brussels, Belgium, 2007.
46. *ASCE 7*; Minimum Design Loads for Buildings and Other Structures. American Society of Civil Engineers (ASCE): Reston, VA, USA, 2010.
47. *SFPE S.01*; Engineering Standard on Calculating Fire Exposures to Structures. Society of Fire Protection Engineers: Bethesda, MD, USA, 2011.
48. Richard, L.P.; Custer, B.J. *Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*; SFPE: Bethesda, MD, USA, 2000.
49. *ASTM E119*; Standard Test Methods for Fire Tests of Building Construction and Materials. ASTM International (ASTM): West Conshohocken, PA, USA, 2012.
50. *ASTM E84*; Standard Test Method for Surface Burning Characteristics of Building Materials. ASTM International: West Conshohocken, PA, USA, 2012.
51. *DIN 4102-1*; Ogniotrwałość Materiałów i Elementów Budowlanych—Sekcja 1: Klasyfikacja Materiałów Budowlanych—Wymagania i Badania. DIN: Berlin, Germany, 2017.
52. *ASTM C569-89*; Standard Test Method for Indentation Hardness of Preformed Thermal Insulations. ASTM International: West Conshohocken, PA, USA, 2016.
53. *ASTM D6513-13*; Standard Practice for Calculating the Superimposed Load on Wood-Frame Walls for Standard Fire-Resistance Tests. ASTM International: West Conshohocken, PA, USA, 2021.
54. *ASTM E176-24a*; Standard Terminology of Fire Standards. ASTM International: West Conshohocken, PA, USA, 2024.
55. *ASTM E177-20*; Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods. ASTM International: West Conshohocken, PA, USA, 2020.

56. *ASTM E691-23*; Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method. ASTM International: West Conshohocken, PA, USA, 2023.
57. *ASTM E814-22*; Standard Test Method for Fire Tests of Penetration Firestop Systems. ASTM International: West Conshohocken, PA, USA, 2022.
58. *ASTM E2226-23*; Standard Practice for Application of Hose Stream. ASTM International: West Conshohocken, PA, USA, 2023.
59. *DIN 50055:1976*; Light Measuring System; Smoke Density Photometric System. Deutsches Institut für Normung (DIN): Berlin, Germany, 1976.
60. *DIN 51622:2020*; Liquefied Petroleum Gases—Propane, Butane, Butene and Their Mixtures—Requirements. Deutsches Institut für Normung (DIN): Berlin, Germany, 2020.
61. *DIN 51900-2:2015*; Testing of Solid and Liquid Fuels—Determination of Gross Calorific Value by the Bomb Calorimeter and Calculation of Net Calorific Value—Part 2: Method Using Isoperibol Calorimeter. Deutsches Institut für Normung (DIN): Berlin, Germany, 2015.
62. *DIN 53436-1:2015*; Generation of Thermal Decomposition Products from Materials for Their Analytic-Toxicological Testing—Part 1: Decomposition Apparatus and Determination of Test Temperature. Deutsches Institut für Normung (DIN): Berlin, Germany, 2015.
63. *EN ISO 1182:2010*; Reaction to Fire Tests for Products—Non-Combustibility Test. CEN: Brussels, Belgium, 2010.
64. *EN ISO 1716:2011*; Reaction to Fire Tests for Building Products—Determination of the Gross Heat of Combustion (Calorific Value). CEN: Brussels, Belgium, 2011.
65. *EN ISO 11925-2:2004*; Reaction to fire tests—Ignitability When Exposed to Direct Flame—Part 2: Single-Flame Source Test. CEN: Brussels, Belgium, 2004.
66. *EN ISO 9239-1*; Reaction to fire tests—Flooring—Part 1: Determination of Burning Behaviour Using a Radiant Heat Source. CEN: Brussels, Belgium, 2025.
67. *EN ISO 13823*; Reaction to Fire Tests for Building Products—SBI Test (Building Products Excluding Floorings). CEN: Brussels, Belgium, 2020.
68. *EN ISO 15725:2011*; Extended Reports on Flame Spread and Other Burning Behaviour of Construction Products and Elements. CEN: Brussels, Belgium, 2011.
69. *EN 1991-1-1:2002*; Eurocode 1: Actions on Structures—Part 1-1: General Actions—Densities, Self-Weight, Imposed Loads for Buildings. CEN-CENELEC Management Centre: Brussels, Belgium, 2002.
70. *PN EN 1991-1-2:2002*; Eurocode 1: Actions on Structures—Part 1-2: General Actions—Actions on Structures Exposed to Fire. CEN. Management Centre: Brussels, Belgium, 2002.
71. *PN-EN 1992-1-2:2004*; Eurocode 2: Design of Concrete Structures—Part 1-2: General Rules—Structural Fire Design. CEN. Management Centre: Brussels, Belgium, 2004.
72. *EN 1995-1-2:2004*; Eurocode 5: Design of Timber Structures—Part 1-2: General Structural Fire Design. CEN. Management Centre: Brussels, Belgium, 2004.
73. Salleh, N.H. Fire Safety in Heritage Buildings: Life Vs Property Safety. *A Soomro Herit. Study Muslim World* **2011**, 61–72. [CrossRef]
74. Akizuki, M.; Hasemi, Y.; Yasui, N.; Kinoshita, K.; Yammamoto, K.; Yoshida, M.; Takeda, M. Fire Safety Studies in the Restoration of a Historic Wooden Townhouse in Kyoto-Fire Safety Experiments on Japanese Traditional Wood-Based Constructions. In Proceedings of the 5th AOSFST, Newcastle, Australia, 3–6 December 2001; 2001; pp. 329–340. Available online: https://www.academia.edu/download/96203056/aofst_5-329.pdf (accessed on 15 October 2025).
75. Shao, P.-C.; Shao, C.-H. Fire-resistant Characteristics of Traditional Buildings in Urban Historic Districts. *E3S Web Conf.* **2018**, *53*, 03053. [CrossRef]
76. Zhou, B.; Jiang, C.; Wang, K.; Romão, X.; Yoshioka, H.; Wang, W.; Zhao, H. A review: The analysis of fires in Chinese historic building and research progress on the fire protection. *Therm. Sci. Eng. Prog.* **2024**, *54*, 102850. [CrossRef]
77. Pillich, C.A. Timber as a Construction Material in Middle- and High-Rise Buildings: The Aesthetics, Merits and Future of Using Wood Considering Fire Regulations and Safety Instructions, Comparing Japan and Austria/Europe. Diploma Thesis, Technische Universität Wien, Vienna, Austria, 2011. Available online: https://resolver.obvsg.at/urn:nbn:at:at-ubtuw:1-41918 (accessed on 15 October 2025).
78. Kincaid, S. After the fire: Reconstruction following destructive fires in historic buildings. *Hist. Environ. Policy Pract.* **2020**, *11*, 21–39. [CrossRef]
79. Watt, I. The Adaptive Monument: Authenticity and Adaptation in Notre-Dame's Post-Fire Revival. Honors Thesis, Department of History, University of Kansas, Lawrence, Kansas, 2025. Available online: https://hdl.handle.net/1808/36150 (accessed on 12 October 2025).
80. Kincaid, S. Practical challenges in mitigating the aftermath of fire in historic buildings. *Hist. Environ. Policy Pract.* **2021**, *12*, 77–96. [CrossRef]

81. Geissler, V. Preservation of historical monuments and fire safety. *Fire Sci. Technol.* **1991**, *11*, 5–8. Available online: https://www.jstage.jst.go.jp/article/fst/11/1%2B2/11_1%2B2_5/_pdf (accessed on 12 October 2025). [CrossRef]
82. Zang, X.; Liu, W.; Wu, D.; Pan, X.; Zhang, W.; Bian, H.; Shen, R. Contemporary fire safety engineering in timber structures: Challenges and solutions. *Fire* **2024**, *7*, 2. [CrossRef]
83. Feilden, B. *Conservation of Historic Buildings*; Routledge: London, UK, 2007.
84. Torero, J.L. Fire safety of historical buildings: Principles and methodological approach. *Int. J. Archit. Herit.* **2019**, *13*, 926–940. [CrossRef]
85. Lostetter, M.O.; Breunese, A. Fire safety aspects in cultural heritage—A case study in historical Delft. *Heron* **2005**, *50*, 321–340. Available online: http://heronjournal.nl/50-4/9.pdf (accessed on 27 August 2025).
86. Nguyen, K.; Navaratnam, S.; Mendis, P.; Zhang, K.; Barnett, J.; Wang, H. Fire safety of composites in prefabricated buildings: From fibre reinforced polymer to textile reinforced concrete. *Compos. Part B Eng.* **2020**, 107815. [CrossRef]
87. Hou, G.; Li, Q.; Song, Z.; Zhang, H. Optimal fire station locations for historic wood building areas considering individual fire spread patterns and different fire risks. *Case Stud. Therm. Eng.* **2021**, *28*, 101548. [CrossRef]
88. Davidson, A.C. BIM and Fire Safety Engineering for Wood Structures. 2023. Available online: https://hdl.handle.net/10315/41755 (accessed on 15 October 2025).
89. Huang, Y.-H. The use of parallel computing to accelerate fire simulations for cultural heritage buildings. *Sustainability* **2020**, *12*, 10005. [CrossRef]
90. Gales, J.; Chorlton, B.; Jeanneret, C. The historical narrative of the standard temperature–time heating curve for structures. *Fire Technol.* **2020**, *57*, 529–558. [CrossRef]
91. Penića, M.; Svetlana, G.; Murgul, V. Revitalization of historic buildings as an approach to preserve cultural and historical heritage. *Procedia Eng.* **2015**, *117*, 883–890. [CrossRef]
92. Buchanan, A.; Östman, B. (Eds.) *Fire Safe Use of Wood in Buildings—Global Design Guide*; CRC Press: Boca Raton, FL, USA; Taylor & Francis Group: Oxford, UK, 2022.
93. Wdowiak-Postulak, A.; Wieruszewski, M.; Bahleda, F.; Prokop, J.; Brol, J. Fibre-reinforced polymers and steel for the reinforcement of wooden elements—Experimental and numerical analysis. *Polymers* **2023**, *15*, 2062. [CrossRef]
94. Liu, T.; Li, A.; Yao, M.; Deng, J.; Huang, Q.; Li, Z.; Li, H.; Yi, X. Fire behavior characteristics and computational simulation research on historic wooden structures. *Fire* **2024**, *7*, 478. [CrossRef]
95. Ariyanayagam, A.; Mahendran, M. Fire safety of buildings based on realistic fire time–temperature curves. In Proceedings of the 19th International CIB World Building Congress, Brisbane, Australia, 5–9 May 2013; QUT: Brisbane, Australia, 2013; pp. 1–13. Available online: https://eprints.qut.edu.au/61929/18/cibwbc2013_submission_380.pdf (accessed on 22 September 2025).
96. Rackauskaite, E.; Kotsovinos, P.; Jeffers, A.; Rein, G. Structural analysis of multi-storey steel frames exposed to travelling fires and traditional design fires. *Eng. Struct.* **2017**, *150*, 271–287. [CrossRef]
97. Naziris, I.A.; Mitropoulou, C.C.; Lagaros, N.D. Innovative Computational Techniques for Multi Criteria Decision Making, in the Context of Cultural Heritage Structures' Fire Protection: Case Studies. *Heritage* **2022**, *5*, 1883–1909. [CrossRef]
98. Walsh, J.J. *The Great Fire of Rome: Life and Death in the Ancient City*; Johns Hopkins University Press: Baltimore, MD, USA, 2019. Available online: https://books.google.com/books?hl=pl&lr=&id=FqKtDwAAQBAJ&oi=fnd&pg=PP8&dq=The+Great+Fire+of+Rome+in+64+wood+building (accessed on 27 September 2025).
99. Field, J.F. *London, Londoners and the Great Fire of 1666: Disaster and Recovery*; Routledge: Oxfordshire, UK, 2017. Available online: https://www.taylorfrancis.com/books/mono/10.4324/9781315099323/london-londoners-great-fire-1666-jacob-field (accessed on 28 September 2025).
100. Yenice, B.; Korkmaz, E. Architectural impact of 19th-century fire regulations: A case study of New York tenement houses. *Mekansal Araştırmalar Derg.* **2023**, *1*, 57–74. Available online: https://dergipark.org.tr/en/download/article-file/3548670 (accessed on 28 September 2025).
101. Fonseca, E.M.M.; Gomes, C. FEM Analysis of 3D Timber Connections Subjected to Fire: The Effect of Using Different Densities of Wood Combined with Steel. *Fire* **2023**, *6*, 193. [CrossRef]
102. Qin, R.; Zhou, A.; Chow, C.L.; Lau, D. Structural performance and charring of loaded wood under fire. *Eng. Struct.* **2021**, *228*, 111491. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.